

# APPLICATION UNDER UNITED STATES PATENT LAWS

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Invention: **DEVICE MANUFACTURING METHOD AND A SUBSTRATE**

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## SPECIFICATION

## **Device Manufacturing Method and a Substrate**

### Field

**[0001]** The present invention relates to a device manufacturing method and a substrate.

### Background

**[0002]** A lithographic apparatus is a machine that applies a desired pattern onto a target portion of a substrate. Lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In that circumstance, a patterning device, such as a mask, may be used to generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (e.g. comprising part of, one or several dies) on a substrate (e.g. a silicon wafer) that has a layer of radiation-sensitive material (resist). In general, a single substrate will contain a network of adjacent target portions that are successively exposed. Known lithographic apparatus include so-called steppers, in which each target portion is irradiated by exposing an entire pattern onto the target portion in one go, and so-called scanners, in which each target portion is irradiated by scanning the pattern through the projection beam in a given direction (the "scanning"-direction) while synchronously scanning the substrate parallel or anti-parallel to this direction.

**[0003]** It has been proposed to immerse at least a portion of a substrate in a lithographic projection apparatus in a liquid having a relatively high refractive index, e.g. water, so as to fill a space between an element of the projection system and the substrate. The point of this is to enable imaging of smaller features since the exposure radiation will have a shorter wavelength in the liquid. (The effect of the liquid may also be regarded as increasing the effective NA of the lithographic projection apparatus and also increasing the depth of focus.)

**[0004]** However, submersing a substrate or a substrate and substrate table in a bath of liquid (see for example United States patent US 4,509,852, hereby incorporated in its entirety by reference) means that there may be a large body of liquid that must be

accelerated during a scanning exposure. This may require additional or more powerful motors and turbulence in the liquid may lead to undesirable and unpredictable effects.

[0005] One of the solutions proposed is for a liquid supply system to provide liquid on only a localized area of the substrate and in between a final element of the projection system and the substrate using a liquid supply system (the substrate generally has a larger surface area than the final element of the projection system). One way which has been proposed to arrange for this is disclosed in PCT patent application WO 99/49504, hereby incorporated in its entirety by reference. As illustrated in Figures 2 and 3, liquid is supplied by at least one inlet IN onto the substrate, preferably along the direction of movement of the substrate relative to the final element, and is removed by at least one outlet OUT after having passed under the projection system. That is, as the substrate is scanned beneath the element in a  $-X$  direction, liquid is supplied at the  $+X$  side of the element and taken up at the  $-X$  side. Figure 2 shows the arrangement schematically in which liquid is supplied via inlet IN and is taken up on the other side of the element by outlet OUT which is connected to a low pressure source. In the illustration of Figure 2 the liquid is supplied along the direction of movement of the substrate relative to the final element, though this does not need to be the case. Various orientations and numbers of in- and out-lets positioned around the final element are possible, one example is illustrated in Figure 3 in which four sets of an inlet with an outlet on either side are provided in a regular pattern around the final element.

### Summary

[0006] In addition to the liquid supply system described above, it also possible is to provide a liquid supply system with a seal member which extends along at least a part of a boundary of the space between an element of the projection system and the substrate table. The seal member is substantially stationary relative to the projection system in the XY plane though there may be some relative movement in the Z direction (in the direction of the optical axis). A seal is formed between the seal member and the surface of the substrate. In an embodiment, the seal is a contactless seal such as a gas

seal. Such a system is disclosed in United States patent application US 10/705,783, filed November 12, 2003, hereby incorporated in its entirety by reference.

[0007] Other types of liquid supply systems are clearly possible including those with different arrangements of inlets and outlets and also those which are asymmetric.

[0008] A difficulty in immersion lithography has been found to be the existence of bubbles and/or particles in the immersion liquid. This is particular problem during scanning of the substrate with respect to the projection system. In this circumstance it is possible that bubbles and/or particles become attached to the substrate surface. These bubbles and/or particles can disrupt the patterned beam so that the quality of the substrate produced may be reduced.

[0009] Accordingly, it would be advantageous, for example, to reduce the effect of bubbles and/or particles in immersion liquid on the quality of the product.

[0010] According to an aspect, there is provided a device manufacturing method comprising:

[0011] - providing an immersion liquid between a substrate and at least a portion of a projection system of a lithographic projection apparatus, wherein a non-radiation sensitive material is carried by said substrate, said non-radiation sensitive material being at least partially transparent to radiation and being of a different material than said immersion liquid, said non-radiation sensitive material being provided over at least a part of a radiation sensitive layer of said substrate; and

[0012] - projecting a patterned beam of radiation, through said immersion liquid, onto a target portion of said substrate using said projection system.

[0013] Bubbles on the surface of a substrate in contact with immersion liquid can be kept far away enough from the radiation sensitive material on the substrate so that their effect on the patterned beam is less than if the bubbles were closer to the radiation sensitive material. If the non-radiation sensitive material is made of sufficient thickness, it is possible that bubbles on the interface between the immersion liquid and the non-radiation sensitive material will only introduce stray light and not seriously affect the quality of the imaged product. The above also works on the same principle for particles which are present in the immersion liquid, as well as, or instead of, bubbles.

[0014] In an embodiment, the non-radiation sensitive material has a thickness and said radiation has a wavelength and said thickness is at least greater than said wavelength. In this way, when the radiation from a projection system passes through the non-radiation sensitive material its wavelength is reduced. This allows the imaging of smaller features on the substrate.

[0015] In an embodiment, the non-radiation sensitive material has a thickness of at least 5  $\mu\text{m}$ . In embodiments, the thickness may be at least 10  $\mu\text{m}$  or at least 20  $\mu\text{m}$ . At these thicknesses, the effects on imaging of the bubbles and/or particles can be dramatically reduced. Also, it has been found that at these thicknesses it is possible to provide immersion liquid between a surface of the non-radiation sensitive material and a portion of the projection system which is effective to reduce the wavelength of the projection beam while aiming to reduce the effects of bubbles and/or particles on imaging quality.

[0016] In an embodiment, the non-radiation sensitive material has a first refractive index and the immersion liquid has a second refractive index, and said first refractive index is at least as large as said second refractive index such that the effect of the non-radiation sensitive material is not to increase the wavelength of the projection beam.

[0017] According to a further aspect, there is provided a substrate for use in a lithographic projection apparatus, the substrate being at least partly covered by a radiation sensitive layer, the radiation sensitive layer being at least partly covered with a non-radiation sensitive material which is at least partly transparent to said radiation and being of a different material than an immersion liquid through which a patterned beam of said radiation of the lithographic projection apparatus is projected onto a target portion of said substrate.

[0018] This substrate may be used in the method(s) described herein.

[0019] According to a further aspect, there is provided a device manufacturing method comprising:

[0020] - providing an immersion liquid, between a substrate and at least a portion of a projection system of a lithographic projection apparatus, to a non-radiation sensitive

material on said substrate, said non-radiation sensitive material, which is at least partially transparent to radiation, provided over at least a part of a radiation sensitive layer of said substrate and having a thickness effective to substantially reduce the effect of at least one of bubbles and particles in said immersion liquid on the quality of a patterned beam impinging on the radiation sensitive layer; and

[0021] - projecting a patterned beam of radiation, through said immersion liquid, onto a target portion of said substrate using said projection system.

[0022] Although specific reference may be made in this text to the use of lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus described herein may have other applications, such as the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal displays (LCDs), thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms “wafer” or “die” herein may be considered as synonymous with the more general terms “substrate” or “target portion”, respectively. The substrate referred to herein may be processed, before or after exposure, in for example a track (a tool that typically applies a layer of resist to a substrate and develops the exposed resist) or a metrology or inspection tool. Where applicable, the disclosure herein may be applied to such and other substrate processing tools. Further, the substrate may be processed more than once, for example in order to create a multi-layer IC, so that the term substrate used herein may also refer to a substrate that already contains multiple processed layers.

[0023] The terms “radiation” and “beam” used herein encompass all types of electromagnetic radiation, including ultraviolet (UV) radiation (e.g. having a wavelength of 365, 248, 193, 157 or 126 nm).

[0024] The term “patterning device” used herein should be broadly interpreted as referring to any device that can be used to impart a projection beam with a pattern in its cross-section such as to create a pattern in a target portion of the substrate. It should be noted that the pattern imparted to the projection beam may not exactly correspond to the desired pattern in the target portion of the substrate. Generally, the pattern imparted

to the projection beam will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit.

[0025] A patterning device may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable LCD panels. Masks are well known in lithography, and include mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. An example of a programmable mirror array employs a matrix arrangement of small mirrors, each of which can be individually tilted so as to reflect an incoming radiation beam in different directions; in this manner, the reflected beam is patterned. In each example of a patterning device, the support structure may be a frame or table, for example, which may be fixed or movable as required and which may ensure that the patterning device is at a desired position, for example with respect to the projection system. Any use of the terms “reticle” or “mask” herein may be considered synonymous with the more general term “patterning device”.

[0026] The term “projection system” used herein should be broadly interpreted as encompassing various types of projection system, including refractive optical systems, reflective optical systems, and catadioptric optical systems, as appropriate for example for the exposure radiation being used, or for other factors such as the use of an immersion fluid or the use of a vacuum. Any use of the term “lens” herein may be considered as synonymous with the more general term “projection system”.

[0027] The illumination system may also encompass various types of optical components, including refractive, reflective, and catadioptric optical components for directing, shaping, or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a “lens”.

[0028] The lithographic apparatus may be of a type having two (dual stage) or more substrate tables (and/or two or more mask tables). In such “multiple stage” machines the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposure.

### Brief Description of the Drawings

[0029] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

[0030] Figure 1 depicts a lithographic apparatus according to an embodiment of the invention;

[0031] Figure 2 illustrates, in cross-section, a liquid supply system for use with an embodiment of the invention;

[0032] Figure 3 illustrates the liquid supply system of Figure 2 in plan;

[0033] Figure 4 illustrates a substrate according to an embodiment of the present invention; and

[0034] Figures 5a and 5b illustrate a conventional substrate and a substrate according to an embodiment of the invention respectively under a projection system during imaging.

### Detailed Description

[0035] Figure 1 schematically depicts a lithographic apparatus according to a particular embodiment of the invention. The apparatus comprises:

[0036] - an illumination system (illuminator) IL for providing a projection beam PB of radiation (e.g. UV radiation).

[0037] - a first support structure (e.g. a mask table) MT for supporting a patterning device (e.g. a mask) MA and connected to a first positioning device PM for accurately positioning the patterning device with respect to item PL;

[0038] - a substrate table (e.g. a wafer table) WT for holding a substrate (e.g. a resist-coated wafer) W and connected to a second positioning device PW for accurately positioning the substrate with respect to item PL; and

[0039] - a projection system (e.g. a refractive projection lens system) PL for imaging a pattern imparted to the projection beam PB by patterning device MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.



[0040] As here depicted, the apparatus is of a transmissive type (e.g. employing a transmissive mask). Alternatively, the apparatus may be of a reflective type (e.g. employing a programmable mirror array of a type as referred to above).

[0041] The illuminator IL receives a beam of radiation from a radiation source SO. The source and the lithographic apparatus may be separate entities, for example when the source is an excimer laser. In such cases, the source is not considered to form part of the lithographic apparatus and the radiation beam is passed from the source SO to the illuminator IL with the aid of a beam delivery system BD comprising, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be integral part of the apparatus, for example when the source is a mercury lamp. The source SO and the illuminator IL, together with the beam delivery system BD if required, may be referred to as a radiation system.

[0042] The illuminator IL may comprise an adjusting device AM for adjusting the angular intensity distribution of the beam. Generally, at least the outer and/or inner radial extent (commonly referred to as  $\sigma$ -outer and  $\sigma$ -inner, respectively) of the intensity distribution in a pupil plane of the illuminator can be adjusted. In addition, the illuminator IL generally comprises various other components, such as an integrator IN and a condenser CO. The illuminator provides a conditioned beam of radiation, referred to as the projection beam PB, having a desired uniformity and intensity distribution in its cross-section.

[0043] The projection beam PB is incident on the mask MA, which is held on the mask table MT. Having traversed the mask MA, the projection beam PB passes through the projection system PL, which focuses the beam onto a target portion C of the substrate W. With the aid of the second positioning device PW and position sensor IF (e.g. an interferometric device), the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the beam PB. Similarly, the first positioning device PM and another position sensor (which is not explicitly depicted in Figure 1) can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval from a mask library, or during a scan. In general, movement of the object tables MT and WT will be realized with the aid of a

long-stroke module (coarse positioning) and a short-stroke module (fine positioning), which form part of the positioning device PM and PW. However, in the case of a stepper (as opposed to a scanner) the mask table MT may be connected to a short stroke actuator only, or may be fixed. Mask MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2.

[0044] The depicted apparatus can be used in the following modes:

[0045] 1. In step mode, the mask table MT and the substrate table WT are kept essentially stationary, while an entire pattern imparted to the projection beam is projected onto a target portion C at one time (i.e. a single static exposure). The substrate table WT is then shifted in the X and/or Y direction so that a different target portion C can be exposed. In step mode, the maximum size of the exposure field limits the size of the target portion C imaged in a single static exposure.

[0046] 2. In scan mode, the mask table MT and the substrate table WT are scanned synchronously while a pattern imparted to the projection beam is projected onto a target portion C (i.e. a single dynamic exposure). The velocity and direction of the substrate table WT relative to the mask table MT is determined by the (de-)magnification and image reversal characteristics of the projection system PL. In scan mode, the maximum size of the exposure field limits the width (in the non-scanning direction) of the target portion in a single dynamic exposure, whereas the length of the scanning motion determines the height (in the scanning direction) of the target portion.

[0047] 3. In another mode, the mask table MT is kept essentially stationary holding a programmable patterning device, and the substrate table WT is moved or scanned while a pattern imparted to the projection beam is projected onto a target portion C. In this mode, generally a pulsed radiation source is employed and the programmable patterning device is updated as required after each movement of the substrate table WT or in between successive radiation pulses during a scan. This mode of operation can be readily applied to maskless lithography that utilizes a programmable patterning device, such as a programmable mirror array of a type as referred to above.

[0048] Combinations and/or variations on the above described modes of use or entirely different modes of use may also be employed.

[0049] Figure 4 depicts a substrate W ready for processing in a lithographic apparatus of, for example, Figures 1 to 3. A layer of radiation sensitive material 2 (i.e. the so called “resist”) is present on top of a surface of the substrate W. The radiation sensitive material 2 is approximately 200 nm thick. A layer 3 of protective material is present above the radiation sensitive material 2 to protect it from contaminants. This protective material is thin. In an embodiment, the thickness is less than one wavelength of the radiation of the projection beam. For example, the layer 3 of protective material may be approximately 80 nm thick.

[0050] A top coating 4 is provided above (e.g., applied to) the layer of protective material 3. The top coating or layer 4 is of a material not sensitive to radiation at the wavelength of the projection beam PB and is at least partially transparent to the radiation of the wavelength of the projection beam PB. In an embodiment, it is different to and immiscible with the immersion liquid. The top coating 4 is, in an embodiment, attached to said substrate W and may be solid. In an embodiment, the top coating 4 transmits at least 80% of the radiation of the projection beam. In embodiment, the top coating 4 may transmit at least 90% or at least 95% of the radiation of the projection beam. In an embodiment, the top coating 4 is also not reactive with the immersion liquid provided by the liquid supply system such as the one illustrated in Figures 2 and 3. It has been found that at a wavelength of 193 nm that water is a suitable liquid for use as an immersion liquid.

[0051] Figures 5a and 5b illustrate how an embodiment of the present invention functions. In Figure 5a, the substrate W is a standard substrate covered, at least in part, with immersion liquid during imaging. Figure 5b illustrates a substrate according to an embodiment of the invention during imaging. As can be seen in Figure 5a, bubbles and/or particles 5 in the immersion liquid in a conventional substrate are only 80 nm away (i.e., the thickness of the protective layer 3) from the radiation sensitive layer 2. In this instance, any bubbles and/or particles on the surface of the substrate can seriously affect the imaging quality, for example, by being within the depth of focus. In contrast, as can be seen from Figure 5b, the top coating 4 keeps any bubbles and/or particles in the immersion liquid at least a distance  $t$  from the radiation sensitive layer 2. Thus, the

effect of the bubbles and/or particles on the imaging quality can be considerably reduced (for example, by having the bubbles and/or particles out of focus) without making the lithographic projection apparatus any more complex.

[0052] In an embodiment, it is desired that the top coating 4 has a refractive index substantially the same as that of the immersion liquid, perhaps within 0.2 or 0.1 of that of the immersion liquid. In this way, optical effects such as those resulting from variations in thickness of the coating 4 can be ignored. Thus, in an embodiment, the top coating 4 has a refractive index greater than that of air, in an embodiment as much as that of the immersion liquid if not more. In an embodiment, the non-radiation sensitive material has a refractive index in the range of 1 to 1.7.

[0053] In an embodiment, the top coating 4 is much thicker than the wavelength of the projection beam. A thickness to bubble and/or particle diameter ratio should be as close as possible to or larger than 10 to 1. The maximum expected bubble and/or particle size is 1  $\mu\text{m}$  so for best performance the thickness of the top coating 4 should be at least 10  $\mu\text{m}$ . In an embodiment, the thickness may be at least 20  $\mu\text{m}$  or at least 30  $\mu\text{m}$  and up to 100  $\mu\text{m}$  above which the coating may become harder to provide and cost prohibitive.

[0054] In an embodiment, the non-radiation sensitive material is substantially insoluble and unreactive in the immersion liquid. If this is not the case, embodiments of the invention will still work but it may be necessary to take dissolution of the top coating 4 into account during imaging of the substrate. In an embodiment, the top coating 4 can be removed with solvents which are typically used with resist processing.

[0055] The top coating 4 may be a layer of water with an anti-evaporation coating or similar to the (conventional) layer 3 of protective material which is a water based gel (conventionally known as a top coat). Polymers or plastics may be suitable.

[0056] It will be apparent that the function of the layer 3 of protective material and the top coating 4 can be performed by one and the same layer applied at the same time with the thicknesses and properties as described above (i.e. an embodiment of the invention can be regarded as a 'thick' top coat).

[0057] While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention.